Amendments to the claims:

Claim 1 (currently amended): An apparatus to manipulate an object comprising: a pair of actuated compliant beams, mounted substantially perpendicular to each other, ~~which can~~ to move substantially in the same plane so as to move into contact with opposing surfaces of an object, to thereby grip and manipulate the object.

Claim 2 (original): The apparatus of claim 1 wherein each compliant beam includes a piezoelectric actuator.

Claim 3 (original): The apparatus of claim 2 wherein one end of the piezoelectric actuator is attached to a proximal end of a base member.

Claim 4 (original): The apparatus of claim 3 wherein a tip member is attached to a distal end of the base member.

Claim 5 (original): The apparatus of claim 4 wherein the tip member has an inclined face configured to engage the object to be manipulated.

Claim 6 (original): The apparatus of claim 5 wherein the face of the tip member is inclined at angle of approximately 45 degrees.

Claim 7 (original): The apparatus of claim 4 wherein a strain gauge is located at a face and back of each of the base member and the tip member.

Claim 8 (original): The apparatus of claim 3 wherein the piezoelectric actuator drives a distal end of the base member.

Claim 9 (original): The apparatus of claim 8 wherein the piezoelectric actuator drives the distal end of the base member through a point contact.

Claim 10 (currently amended): The apparatus of claim ~~2~~ 1 further including a tip member joined to one end of ~~the piezoelectric actuator~~ each compliant beam.

Claim 11 (original): The apparatus of claim 1 wherein each compliant beam includes an actuator selected from the group consisting of a thermal actuator, a motor-driven beam actuator, a polymer/thermal actuator, and a flexible circuit actuator.

Claim 12 (original): The actuator of claim 1 further including at least one strain gauge to measure a deflection of a beam or a force applied by a beam.

Claim 13 (original): The apparatus of claim 1 wherein one of the beams can only be driven along a first axis, while the other one of the beams can only be driven along a second axis that is perpendicular to the first axis.

Claim 14 (original): The apparatus of claim 13 wherein each beam is fixed to a surface.

Claim 15 (currently amended): An apparatus to manipulate an object comprising:

a first arm that is actuated only along a first axis;

a second arm that is actuated only along a second axis that is substantially perpendicular to the first axis; and

the first and second arms movable substantially in the same plane and defining a space therebetween in which an object can be positioned such that the first arm can move into contact with a first surface of the object and the second arm can move into contact with a second surface of the object, whereby the first and second arms can grip and manipulate the object.

Claim 16 (currently amended): A system to manipulate an object comprising:

a first arm that is actuated only along a first axis;

a second arm that is actuated only along a second axis that is substantially perpendicular to the first axis; and

the first and second arms movable substantially in the same plane and defining a space therebetween in which an object can be positioned such that the first and second arms can move into contact with respective opposite surfaces of the object to grip and manipulate the object; and

an XYZ stage on which the object can be positioned.

Claim 17 (currently amended): A method of manipulating an object comprising:

~~grasping one side of the object with~~ bringing a first arm that is actuated only along a first axis into contact with one side of the object;

~~grasping another side of the object with~~ bringing a second arm that is actuated only along a second axis that is substantially perpendicular to the first axis into contact with another side of the object; and

actuating at least one of the first and second arms, the first and second arms being movable in substantially the same plane, to manipulate the object.

Claim 18 (original): The method of claim 17 wherein the first and second arms are actuated to roll the object.

Claim 19 (original): The method of claim 17 wherein the first and second arms are actuated to pick and place the object.

Claim 20 (original): The method of claim 17 wherein the first and second arms are actuated to reorient the object perpendicular to a grasping wall.

Claim 21 (original): The method of claim 17 wherein the first and second arms are actuated to align the object along a wall.

Claim 22 (currently amended): A method of manipulating a submillimeter-sized object comprising:

~~gripping one side of the object with~~ bringing a first actuated compliant beam into contact with one side of the object;

~~gripping another side of the object with~~ bringing a second actuated compliant beam that is mounted substantially perpendicular to the first beam into contact with another side of the object; and

operating the first and second beams so that they move in the same plane to manipulate the object.

Claim 23 (currently amended): A method of manipulating an object comprising:

~~grasping~~ contacting one side of the object with a first beam that is actuated only along a first axis;

~~grasping~~ contacting another side of the object with a second beam that is actuated only along a second axis that is perpendicular to the first axis;

positioning the object in a groove in a wall as the object is grasped by the first and second beams;

controlling the position of the wall and the first beam such that the wall and the first beam grasp the object, while the second beam is transferred to another side of the object;

controlling the position of the wall and the second beam such that the wall and the second beam grasp the object, while the first beam is transferred to yet another side of the object;

moving the wall away from the object; and

operating the first and second beams to rotate the object 90 degrees.

Claim 24 (original): The method of claim 23 wherein the steps thereof are repeated to rotate the object 360° degrees.

Claim 25 (new): An apparatus to manipulate an object comprising:

a first compliant arm that is actuated only along a first axis;

a second compliant arm that is actuated only along a second axis that is substantially perpendicular to the first axis; and

the first and second arms capable of being selectively brought into contact with respective opposite surfaces of an object, with the motion of the first and second arms being substantially coplanar, to thereby grip and manipulate the object.

Claim 26 (new): The apparatus of claim 1 wherein the angle between the opposing surfaces is less than twice the friction angle of the opposing surfaces.

REMARKS

CLAIM REJECTIONS UNDER 35 U.S.C. 112

Figures 1, 2 and 7A-7C

Claims 1-24 stand rejected under 35 U.S.C. 112 as Figure 1 was said to be inconsistent with Figures 2 and 7A-7C. However, Figures 2 and 7A-7C are, in fact, consistent with Figure 1.

Figure 1 is a schematic view of a system for manipulating an object including ortho-tweezers and an XYZ stage. As shown, the tip of an arm 14 is movable in the x direction, while the tip of an arm 16 is movable in the y direction.

Figure 2 is a schematic representation of a grasping configuration of the arms 14 and 16. Figures 7A-7C are schematic views illustrating a technique for rolling an object using the arms 14 and 16. As shown in Figures 2 and 7A-7C, the arm 14 can move or translate along the x-axis as represented by a spring element 14a. However, it is prevented from moving along the y-axis as represented by a constraint element 14b. The arm 16, on the other hand, can move or translate along the y-axis as represented by a spring element 16a. However, it is prevented from moving along the x-axis as represented by a constraint element 16b.

Figures 2 and 7A-7C, as would be understood by one skilled in this art, are simply classic approximations of what is shown in Figure 1. As such, these figures are consistent with Figure 1. See, for example, Hanafusa and Asada, "A Robot Hand with Elastic Fingers and its Application to Assembly Process", IFAC International Symposium on Information-Control Problems in Manufacturing Technology, Tokyo, Japan, October 1977.

The Grip

Claims 1-24 also stand rejected under 35 U.S.C. 112 as the arms were said to provide a grip only if applied to opposite, parallel surfaces of an object and that the grip was insufficient to lift an object. However, this is simply not the case.

The arms can grip as well as lift an object if they contact opposing surfaces of an object such that the angle between the opposing surfaces, the included angle, is less than twice the friction angle. If the angle between the opposing surfaces is less than twice the friction angle, the grip will be stable. Conversely, if the angle between the opposing surface is greater than twice the friction angle, the object will slip from the grip.

The surfaces do not need to be parallel to each other, and the arms are capable of lifting an object if the above-noted condition is satisfied. See, Applicant's specification at page 5, lines 9-12; page 10, line 29 to page 11, line 2.

Gripping or Grasping

Claims 17-24 stand rejected as there is no disclosure of a single beam capable of gripping or grasping one side of an object. The claims have been amended to specify than an individual arm or beam contacts an object, as opposed to gripping or grasping it.

CLAIM REJECTIONS UNDER 35 U.S.C. 102(a) AND 103(a)

Claims 1-3, 11, 13-15 and 17-22 stand rejected under 35 U.S.C. 102(a) as anticipated by Smits (U.S. Patent No. 5,049,775), Ivanov (U.S. Patent No. 3,928,778), McNaney (U.S. Patent No. 3,146,367), Assard (U.S. Patent No. 4,523,120), or Zumeris (U.S. Patent No. 5,696,421). Claim 10 stands rejected as anticipated by Zumeris, Smits or McNaney.

Claims 4-6, 8 and 9 stand rejected under 35 U.S.C. 103(a) as unpatentable over Smits or McNaney in view of Tygart (U.S. Patent No. 3,336,529). Claims 7 and 12 stand rejected as unpatentable over Smits or McNaney in view of Tygart as applied to claim 4 above, and further in view of Hatamura (U.S. Patent No. 4,686,440). Claim 16 stands rejected as unpatentable over Smits, McNaney or Zumeris in view of Hatamura, Chang (U.S. Patent No. 6,359,370) or Rogallo (U.S. Patent No. 3,304,773).

The claims have been amended to patentably distinguish over the cited art. Claim 1, for instance, calls for a pair of actuated compliant beams, mounted substantially perpendicular to each other, to move substantially in the same plane so as to move into contact with opposing surfaces of an object to thereby grip and manipulate the object.

Smits

Smits, as shown in Figure 4, discloses a rotary unit driven by two machines 64 and 66 that are mounted or integrally attached to a frame 68. The machines 64 and 66 are operated in tandem to rotate a wheel 60. The feet of both machines mesh with teeth 62 located around the perimeter of the wheel. The feet move up and down, and twist to rotate the wheel.

The feet of Smits' machines do not move in the same plane. They move in perpendicular planes. Thus, Applicants' claimed invention is patentably distinct from Smits.

Iranov, McNaney, Assard, and Zumeris

Applicants' claimed invention is also patentably distinct from these references. The compliant beams of Applicants' invention are mounted perpendicular to each other to move in the same plane and into contact with opposing surfaces of an object to grip and manipulate the object.

The actuators of Iranov, McNaney, Assard, and Zumeris are arranged in opposing parallel pairs. One pair of actuators is located in a first plane, and a second pair of actuators is located in a second plane that is perpendicular to the first plane. The pair of actuators in each plane causes movement in that plane. The actuators that are mounted perpendicular to each other do not move in a coplanar fashion, and do not act together to move an object. Moreover, these actuators are not brought into contact with an object to manipulate it. Rather, these actuators are affixed to the object, or they are located in a fixed position relative to the object.

Ivanov discloses a coordinate table 1 holding an article 2. Piezoelectric plates 3 and 4 are arranged in one plane to move the coordinate table 1 with the article 2 thereon along the coordinate x. The plates 3 and 4 are fixedly connected to the coordinate table by springs 6 and 7. Piezoelectric plates 10 and 11 are arranged in a plan perpendicular to the plane of plates 3 and 4. The plates 10 and 11 cause the displacement of the coordinate table 1 with the article 2 thereon along the coordinate y. The plates 10 and 11 are fixedly connected to the coordinate table by springs 12 and 13.

McNaney operates in a similar fashion. The device of McNaney includes four actuators 10a, 10b, 10c and 10d. Each actuator is coupled to a matrix 20 by a rigid rod or yoke. When the actuators 10a and 10b are energized, they act in a "push-pull" manner to move matrix 20 in the direction of arrow 22. Similarly, when the actuators 10c and 10d are energized, they also act in a "push-pull" manner to move the matrix in the direction of arrow 24. Also, as shown in the embodiment of Figure 3, the actuators are not mounted in the same plane as one actuator extends above the other. The motion of the actuators is thus not coplanar. Additionally, the object to be manipulated, the matrix 20, is affixed to the actuators by yokes 25a and 25b.

Assard discloses a bearing support dither 10, including a piezoelectric dithering means 14. The dithering means comprises a first pair of vertically extending ceramic members 20a and a second pair of vertically extending parallel ceramic members 20b arranged orthogonally with respect to the first pair of members 20a. A jewel bearing support 16 is attached to the ceramic members by an elastometer 44.

Zumeris discloses a device for providing two-dimensional movement to a partially spherical element 10 such as a housing for a lens 12. The device includes four rotation units 22a, 22b, 22c and 22d. The four rotation units are divided into two pairs, where each pair operates to provide movement about one axis. The units 22b and 22d provide rotation about an axis 36. The units 22a and 22c provide rotation about an axis 38 perpendicular to the axis 36. Each rotation

unit 20a-20d comprises a motor 40 and an axis defining unit 42. Each axis defining unit includes a support 52 on which the lens 12 rests.

The actuators of Ivanov, McNaney, Assard and Zumeris are each arranged in pairs that are located in planes that are perpendicular to each other. The actuators that are parallel to each other, for example, actuators 10c and 10d of McNaney, cause movement of an object. However, the actuators that are perpendicular to each other, for example, the actuators 10a and 10d of McNaney, do not cause movement of the object. Additionally, the actuators of these references are all attached to the object they are designed to move, such as by the rods of McNaney, or they are located in a fixed position relative to the object. These actuators are not moved into contact with an object, to grip and manipulate the object. Applicants' claimed invention is therefore patentably distinct from these references.

ALLOWABLE CLAIMS

Claims 23 and 24 were said to be allowable if rewritten or amended to overcome the rejections under 35 U.S.C. 112. As discussed above, the rejection of these claims under 35 U.S.C. 112 should be withdrawn.

NEW CLAIMS

Claims 25 and 26 have been added by this amendment. Claim 25 calls for an apparatus to manipulate an object. The apparatus comprises a first compliant arm that is actuated only along a first axis and a second compliant arm that is actuated only along a second axis that is substantially perpendicular to the first axis. The first and second arms are capable of being selectively brought into contact with respective opposite surfaces of an object, with the motion of the first and second arms being substantially coplanar, to grip and manipulate the object. Claim 26 specifies that the angle between the opposing surface of an object is less than twice the

friction angle of the opposing surfaces. It is respectfully submitted that these claims are also patentably distinct from the cited references.

CONCLUSION

In view of the foregoing, it is submitted that all the claims are now in condition for allowance. Accordingly, allowance of the claims at the earliest possible date is requested.

If prosecution of this application can be assisted by telephone, the Examiner is requested to call Applicants' undersigned attorney at (510) 495-3206.

Please apply any other charges or credits to Deposit Account No. 500388.

Respectfully submitted,
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